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Sex- and age-related differences in half-marathon performance and competitiveness in the World's largest half-marathon – The GöteborgsVarvet

Knechtle B[1,2], Nikolaidis PT [3]

[1]Gesundheitszentrum St. Gallen, St. Gallen, Switzerland

[2]Institute of Primary Care, University of Zurich, Zurich, Switzerland

[3]Exercise Physiology Laboratory, Nikaia, Greece

Corresponding author
Prof. Dr. med. Beat Knechtle
Facharzt FMH für Allgemeinmedizin
Gesundheitszentrum St. Gallen
Vadianstrasse 26
9001 St. Gallen
Switzerland
Telefon +41 (0) 71 226 93 00
Telefax +41 (0) 71 226 93 01
E-Mail beat.knechtle@hispeed.ch

Abstract

In road runners, the age-related performance decline has been well investigated for marathoners, but little is known for half-marathoners. We analysed data from 138,616 runners (48,148 women and 90,469 men) competing between 2014 and 2016 in GöteborgsVarvet, the World's largest half-marathon. The men-to-women ratio in participants increased with age, the fastest race times were observed in age groups <35 and 35-39 years in women and in age group 35-39 years in men, the main effect of sex and the sex×age group interaction on race time were trivial, and the competitiveness was denser in men and in the younger age groups. In summary, in half-marathon running in the largest half-marathon in the world, the GöteborgsVarvet,women achieved the fastest race time at an earlier age compared to men where the fastest race times were observed in women in age groups <35 and 35-39 years and in men in age group 35-39 years.

Keywords: aging, competition density, endurance, gender, long-distance running

Introduction

In endurance sport, every distance or length of an endurance performance has its specific age (Allen & Hopkins, 2015). The knowledge of this specific age is important for athletes and coaches to specifically prepare for a certain race distance in order to achieve the best performance.

Half-marathon running is apart from marathon running of high popularity as indicated by race data in the USA (www.runningusa.org/half-marathon-report-2016). Data from races held in Switzerland indicate that the number of half-marathoners and marathoners increased in the last years (Knechtle, Nikolaidis, Onywera, et al., 2016). However, more athletes competed in half-marathons than in marathons. There were 12.3 times more female half-marathoners than female marathoners and 7.5 times more male half-marathoners than male marathoners. Considering a large sample of 508,108 age group runners (*i.e.*125,894 female and 328,430 male half-marathoners and 10,205 female and 43,489 male marathoners) competing between 1999 and 2014 in Switzerland, half-marathoners were younger and slower than marathoners for both women and men (Knechtle, Nikolaidis, Onywera, et al., 2016).

The age of peak marathon performance is well investigated for top athletes and is reported to be between 25 and 35 years depending upon sex, nationality, performance level and kind of analysis (Aschmann et al., 2013; Hunter, Stevens, Magennis, Skelton, & Fauth, 2011; Knechtle, Aschmann, et al., 2016; Knechtle, Assadi, Lepers, Rosemann, & Rüst, 2015; Knechtle, Nikolaidis, Rosemann, & Rüst, 2016; Lara, Salinero, & Del Coso, 2014; Lehto, 2016; Nikolaidis, Onywera, & Knechtle, 2016).

However, little is known for the age of peak half-marathon performance (Aschmann et al., 2013; Knechtle, Nikolaidis, Onywera, et al., 2016; Knechtle, Nikolaidis, Rosemann, et al., 2016; Nikolaidis et al., 2016). A study investigating 125,894 female and 328,430 male half-marathoners competing in all flat half-marathons held in Switzerland between 1999 and 2014 showed that women and men were at about the same age (Knechtle, Nikolaidis, Zingg, Rosemann, & Rüst, 2016).

Especially, the age-related performance decline in half-marathoners is not well investigated. Leyk et al. (2007) analysed 144,040 half-marathon race times to investigate the age-related performance decline in half-marathon running. When the top ten runners were analyzed, race times were virtually identical for age groups 20-49 years. When all finishers were included in each age group running times are almost identical for age groups 25, 35, and 45 years. They concluded that the age-related performance decline started after the age of 50 years in half-marathon running. When Leyk et al. (2007) analysed the running performance of the top-ten athletes for each age group (*i.e.* six decades, 20-79 years), both sexes showed significant age-related increases in running times beyond the age group of 35 years. Unfortunately, in their analyses, they separated the runners in 10-year age groups which might not be very specific for a detailed analysis where 5-year age groups are needed.

The aim of the present study was, therefore, to determine the age-related performance decline in 5-year age groups in female and male half-marathoners competing in the largest half-marathon in the world, the GöteborgsVarvet. Each year, more than 60,000 athletes compete in the race. Based upon recent findings on the relationship between age and endurance performance (Allen & Hopkins, 2015) we hypothesized that the age-related decline in half-marathoners would start earlier than reported for marathoners (Leyk et al., 2007) but at about the same age for women and men (Knechtle, Nikolaidis, Zingg, Rosemann, & Rüst, 2016).

Methods

Ethics approval

This study was approved by the Institutional Review Board of Kanton St. Gallen, Switzerland, with a waiver of the requirement for informed consent of the participants as the study involved the analysis of publicly available data.

Data sampling and data analysis

To avoid a selection bias by collecting data from different races with different race courses and environmental conditions (*e.g.* heat, cold, rain *etc.*) (Ely, Cheuvront, Roberts, & Montain, 2007; Vihma, 2010), we considered only one race with the largest half-marathon in the World, the GöteborgsVarvet. The race is annually held in the middle of May and the environmental conditions were very similar in the three editions 2014-2016 (www.timeanddate.com/weather/sweden/goteborg/historic). On May 27 2014, there was full sunshine and the temperature at noon was 21 °C. On May 23 2015, the temperature at noon was 14 °C and again full sunshine. And on May 22 2016, the temperature was 22 °C and full sunshine.

The data were obtained from the race website www.goteborgsvarvet.se. Participants in the present study were all runners who successfully finished the race. Age groups are provided in the results since 2014 and we therefore included the years 2014-2016 in our analysis. Following the race results, participants younger than 35 years were classified in a single group (*i.e.*U35, 17-35 years), whereas those older than 35 years were classified in 5-year age group intervals from 35-39 to 80-84 years (*i.e.* U40, U45, U50, U55, U60, U65, U70, U75, U80, and O80).

Statistical analysis

The statistical software IBM SPSS v.23.0 (SPSS, Chicago, USA) performed all statistical analyses. For all analyses, statistical significance was determined at an alpha level of 0.05. Mean values and standard deviation (*s*) were calculated for race time. Men-to-women ratio examined the variation of participation by sex. A two-way analysis of variance (ANOVA) compared the main effects of sex and age group on race time. Subsequent comparisons among age groups were carried out using post-hoc Bonferroni test. The magnitude of these differences was examined using effect size eta squared (η^2) and evaluated as: small ($0.010<\eta^2\leq0.059$), moderate ($0.059<\eta^2\leq0.138$) and large ($\eta^2>0.138$) (Cohen, 1988). In addition, we examined sex differences in race time using the formula 100×(men's race time–women's race time)/women's race time. We also compared variations in race time by participants' sex and age group using a mixed-effects regression model. In this model, participants were assigned as random variable, whereas sex and age group were assigned as fixed variables. We examined interaction effects among these fixed variables. Akaike information criterion (AIC) was used to select the final model. Moreover, the coefficient of density (CD) was calculated for each age group by sex from the formula $CD=n_{finish}/(t_{last}-t_{first})$, where n_{finish} the number of participants in the race, t_{last} the race time of the last participant and t_{first} the race time of the first participant.

Results

A total of 138,616 runners (48,148 women and 90,469 men) were considered. The men-to-women ratio ranged from 1.39 (U35) to 12.63 (U80) (Table 1). For all age groups till U65, a consistent trend was observed where men-to-women ration was higher in each age group compared to its younger one. The distribution of race time by sex was shown in Figure 1.

For all participants, a small main effect of age group on race time was observed ($p<0.001$, $\eta^2=0.051$), where U40 had the fastest time and U80 and O80 had the slowest time. A trivial main effect of sex on race time was shown ($p<0.001$, $\eta^2=0.001$), where men were faster than women (1:58:15±0:20:04 vs. 2:11:44±0:19:58 h:min:s, respectively). Also, a trivial sex×age group on race time was observed ($p<0.001$, $\eta^2<0.001$), where sex difference was the least in U65 (men were faster by -9.1% than women) and the largest in U80 (-15.9%). This analysis was in agreement with the mixed-effects regression analysis (Table 2).

In women, race time differed with small magnitude by age group ($p<0.001$, $\eta^2=0.052$) with the fastest time shown in U35 and U40, and the slowest in U75, U80 and O80 (Figure 2). In men, race time differed with medium magnitude by age group ($p<0.001$, $\eta^2=0.082$) with the fastest time observed in U40 and the slowest in U80 and O80.

When only the ten fastest runners of each age group by sex were considered, a large main effect of sex on race time ($p<0.001$, $\eta^2=0.669$) was observed with men being faster than women by 4.8% (1:31:08±0:24:31 vs. 1:35:43±0:19:00 h:min:s, respectively) (Figure 3). Also, a large main effect of age group on race time was shown ($p<0.001$, $\eta^2=0.953$) with U35 being the fastest and O80 the slowest. A large sex×age group interaction on race time was found ($p<0.001$, $\eta^2=0.348$), with sex difference being relatively similar in age groups of U35 till U65 (~10-14%) and higher in U70 and U75 (~21-23%).

The coefficient of density was higher in men than in women (6.04 *versus* 3.48 competitors per second, respectively) (Figure 4). Also, it was the highest in the youngest age group (U35) and the lowest in the oldest age group (O80).

Discussion

The main findings of the present study were that (*i*) the men-to-women ratio in participants increased with age, (*ii*) the fastest race time was observed in U35 (*i.e.* 17-34 years) and U40 (*i.e.* 35-39 years) in women and in U40 (*i.e.* 35-39 years) in men, (*iii*) the main effect of sex and the sex×age group interaction on race time were trivial, (*iv*) when we considered only the fastest ten runners in each age group by sex, large main effects of sex, age group and sex×age group interaction on race time were observed, and (*v*) the competitiveness was more dense in men and in the younger age groups.

The men-to-women ratio in participants increased with age

A first important result of this study was the trend concerning the participation by sex. Although more men participated overall, the men-to-women ratio was lower in the younger than in the older age groups. In other terms, the number of men increased with increasing age relative to women whereas the number of women decreased with increasing age relative to men.

This trend is different to other sports disciplines such as pool swimming where the men-to-women ratio remained unchanged across age groups in master breaststroke (Knechtle, Nikolaidis, Rosemann, et al., 2016) and backstroke swimmers (Unterweger, Knechtle, Nikolaidis, Rosemann, & Rüst, 2016) competing in 50m, 100m and 200m. In master freestyle swimmers competing from 50m to 800m, the men-to-women ratio remained unchanged in age groups 25-29 to 75-79 years in 50m, 100m, and 400m but increased in 200m and 800m. For age groups 80-84 to 85-89 years, the men-to-women ratio remained unchanged in 50m and 100m but decreased in 200m to 800m (Knechtle, Nikolaidis, König, Rosemann, & Rüst, 2016). A very likely explanation for the difference between half-marathon running and pool swimming in different disciplines could be the length of the duration. Half-marathon running takes a considerably longer time than swimming 50m to 800m. Elderly people have a lower skeletal muscle mass compared to younger people and therefore a lack of force to compete over longer distances such as a half-marathon (Laforest, St-Pierre, Cyr, & Gayton, 1990). An increase in age leads to changes in skeletal muscles (*e.g.* decrease in fibers, sarcopenia) which causes weakness and disability (Seene & Kaasik, 2012).

The age of the fastest race time differed by sex

With regards to the effect of age group on race time two major findings were observed. First, the fastest race time was observed in U35 and U40 in women and in U40 in men; and second, the magnitude of this effect was larger in men than in women. In other terms, women achieved their best half-marathon race time ~5 years earlier than men. This is in contrast to existing findings where Leyk et al. (2007) reported that running times of half-marathoners remained almost stationary from 20 to 50 years for both women and men when all athletes were considered. When Leyk et al.(2007) analysed the running performance of the top-ten athletes for each age group, women and men showed a significant age-related decline in performance after the age group of 35 years. However, we have a difference between the sexes. A very likely explanation for the different findings is the fact that we included all women and men in all age groups in 5-year intervals and eliminated therefore a selection bias. Most importantly, the men-to-women ratio changes across age groups.

The main effect of sex and the sex×age group interaction on race time were trivial

An important finding was that the main effect of sex and the sex×age interaction on race time were trivial, which practically implied no sex difference and no variation of sex difference by age group, respectively. This similar performance in women and men should be attributed to the performance level of participants. It was self-evident that due to their very large number, participants in this half-marathon should be categorized as recreational athletes. This finding was in agreement with recent research in recreational athletes (Knechtle, Nikolaidis, Zingg, et al., 2016), but opposed findings on elite runners (Nikolaidis et al., 2016). Particularly, a similar performance between women and men was shown in a study of half-marathons held in Switzerland between 1999 and 2014 (Knechtle, Nikolaidis, Zingg, et al., 2016). On the other hand, men were faster than women by ~9:30 min:sec in a study of the world's best runners during 1999-2015 (Nikolaidis et al., 2016).

Analysis of the fastest ten runners of each age group by sex

In addition to the analysis of all runners, we also examined the fastest ten runners of each age group by sex. Briefly, compared with the analysis of all runners, when only the fastest ten per age groups were analyzed, we observed larger magnitude of main effects of sex and age group as well as of sex×age group interaction, which were accompanied by larger sex differences in race time. When the ten fastest runners for each age group were considered, the younger runners were faster than the older runners confirming the findings of Leyk et al. (2007) when they analysed the top ten half-marathoners in their sample. However, the inclusion of all athletes per age group excludes the sample bias and respects the performance of the age group since the mean and standard deviation of the result represents the large number of athletes in those age groups with more finishers (Will Hopkins, personal communication). Indeed, respecting all athletes per age group is a strength of the study, not a limitation and represents the large amount of work to collect all data

The competitiveness was denser in men and in the younger age groups

Another important result was that the competitiveness was denser in men and the younger age group. CD was a measure of participants' density and was directly influenced by participants' number. Thus, based on the number of participants by sex and age group, it was expected denser CD in men and in younger age groups (Table 1). CD was a calculation similar to the volumetric mass density, *i.e.* density as mass per unit of volume, and was dependent on extreme race times (Grobler, Ferreira, & Terblanche, 2015). Despite its simplicity to calculate, it provided insights with regards to the competitiveness of half-marathon by sex and age groups (see Practical Applications section).

Limitations, strength and implications for future research

The fact that U35 age group covered a large range of age (*i.e.*17-35 years) did not facilitate to provide more details on the age of the fastest race time and presents a limitation. The strength of this study was the large number of participants in this competition and the inclusion of all finishers in each age group. Combining several races with different race courses and environmental conditions would lead to a selection bias. Future studies need to analyze a very large sample of female and male half-marathoners using non-linear regression analyses and separating athletes in 1-year intervals to determine the very specific age of half-marathon running performance.

Practical applications

Athletes and their coaches should be aware of the competitiveness of GöteborgsVarvetas this varied by sex (*i.e.* denser in men) and age group (*i.e.* denser in younger). Thus, the relatively lower CD in women and in the older age groups should encourage more participants from these groups to participate in HM.This information would be useful for "recreation" runners and coaches of "recreational" runners as the majority of the runners in this study completed the half marathon distance between 1:45 and 2:30 h:min. Older age group runners might be motivated by the fact that the participation in older age groups is lower compared to younger age groups and therefore the possibility to achieve a podium in the age group category increases with increasing age. Furthermore, older age group athletes might be motivated to set a new world record in their specific age group (https://mybestruns.com/world_records.php, www.mastersathletics.net/). It has been recently shown that also athletes older than 100 years are able to set age group world records which are approved by the responsible federations (Lepers, Stapley, & Cattagni, 2016).

Conclusions

In half-marathon runningin the largest half-marathon in the world, the GöteborgsVarvet, women achieved the fastest race time at an earlier age compared to men where the fastest race times were observed in U35 (*i.e.* 17-34 years) and U40 (*i.e.* 35-39 years) in women and in U40 (*i.e.* 35-39 years) in men.

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Table 1 Number of participants by sex and age group

Age groups	Sex		Total	Men-to-women ratio
	Women	Men		
U35	20,176	27,951	48,127	1.39
U40	7,506	13,998	21,504	1.86
U45	7,636	15,512	23,148	2.03
U50	5,984	12,824	18,808	2.14
U55	3,968	9,396	13,364	2.37
U60	1,771	5,651	7,422	3.19
U65	749	3,012	3,761	4.02
U70	259	1,504	1,763	5.81
U75	88	500	588	5.68
U80	8	101	109	12.63
O80	3	19	22	6.33
Total	48,148	90,468	138,616	1.88

Table 2 Mixed-effects regression analysis

Age group	Parameter	Estimate	Standard error	Significance
U35	C	8631.34	17.67	<0.001
	Sex	-864.33	10.67	<0.001
U40	C	8644.16	27.38	<0.001
	Sex	-891.46	15.93	<0.001
U45	C	8750.13	26.80	<0.001
	Sex	-908.35	15.44	<0.001
U50	C	8821.43	31.34	<0.001
	Sex	-840.27	17.96	<0.001
U55	C	9255.51	40.26	<0.001
	Sex	-962.98	22.83	<0.001
U60	C	9480.46	62.65	<0.001
	Sex	-938.26	34.57	<0.001
U65	C	9533.55	96.58	<0.001
	Sex	-794.68	52.36	<0.001
U70	C	10489.73	161.81	<0.001
	Sex	-1098.06	85.77	<0.001
U75	C	11364.13	327.98	<0.001
	Sex	-1285.91	174.05	<0.001
U80	C	13265.01	1345.73	<0.001
	Sex	-1824.13	692.19	0.010
O80	C	13712.23	1875.60	<0.001
	Sex	-1769.56	989.79	0.088

Figure legends

Figure 1 Distribution of race time in women (A) and men (B).The dashed line depicts the curve of normal distribution.

Figure 2 Race time by sex and age group considering all runners. Error bars denote ±2 standard error. All sex and age groups differ among them ($p<0.05$).△ = women, ○ = men.

Figure 3 Race time by sex and age group considering the ten fastest runners in each age group by sex. Error bars denote ±2 standard deviations. All sex and age groups differ among them ($p<0.05$). △ = women, ○ = men.

Figure 4 Competition densities by sex and age group.△ = women, ○ = men.

Figure 1

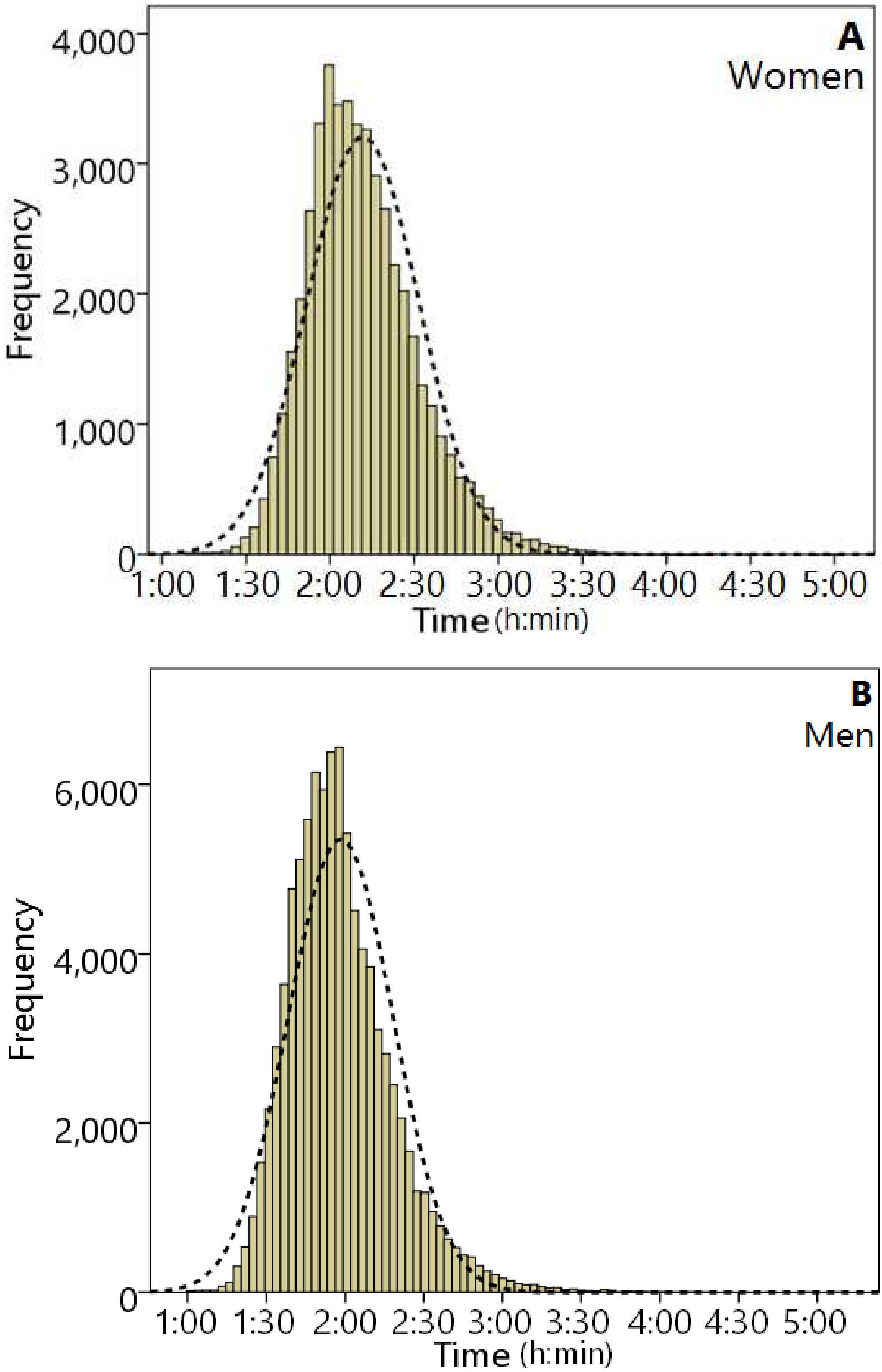
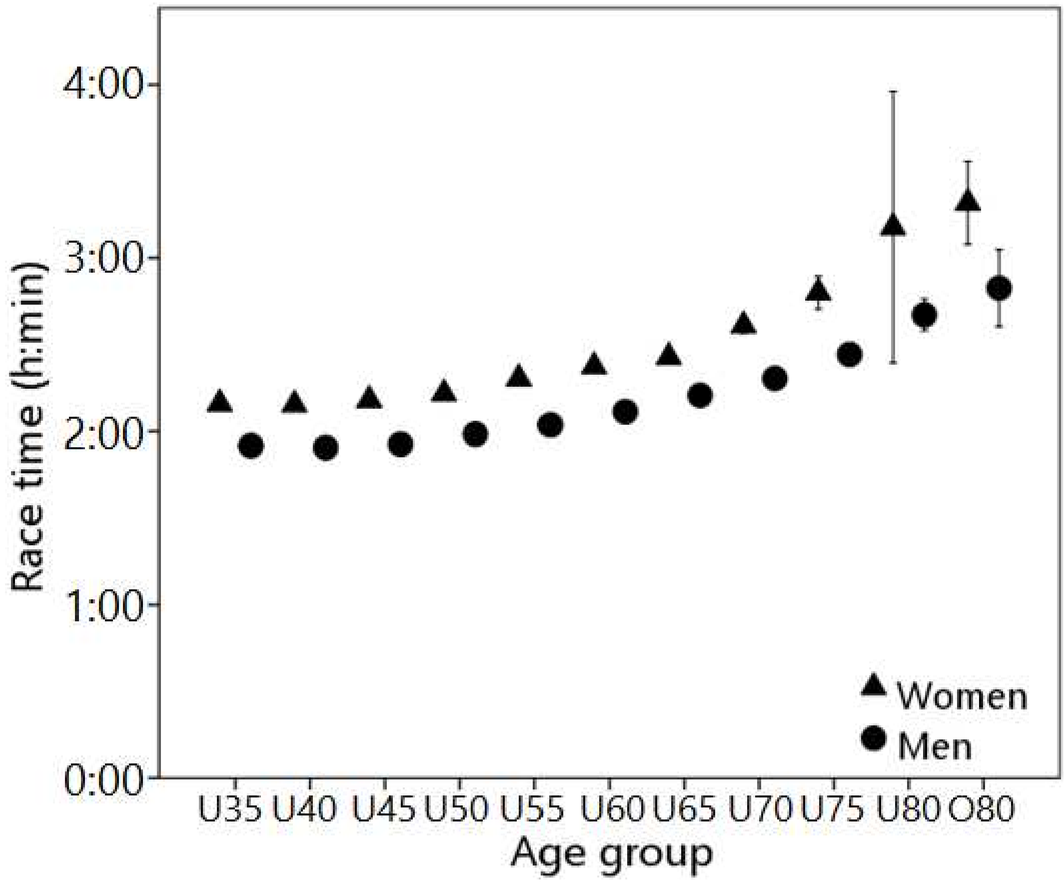
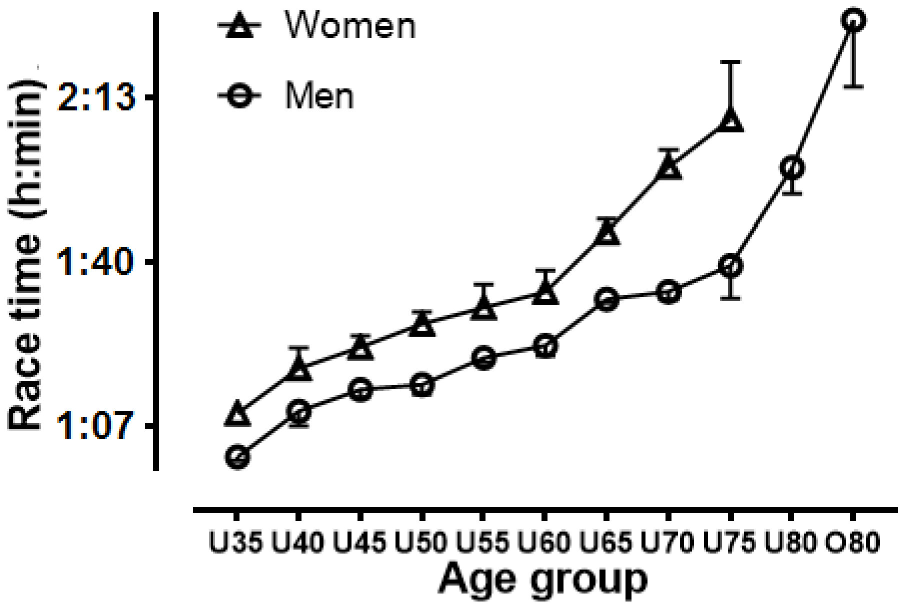

A
Women
Frequency
4,000
3,000
2,000
1,000
0
1:00 1:30 2:00 2:30 3:00 3:30 4:00 4:30 5:00
Time (h:min)
B
Men
Frequency
6,000
4,000
2,000
0
1:00 1:30 2:00 2:30 3:00 3:30 4:00 4:30 5:00
Time (h:min)

Figure 2



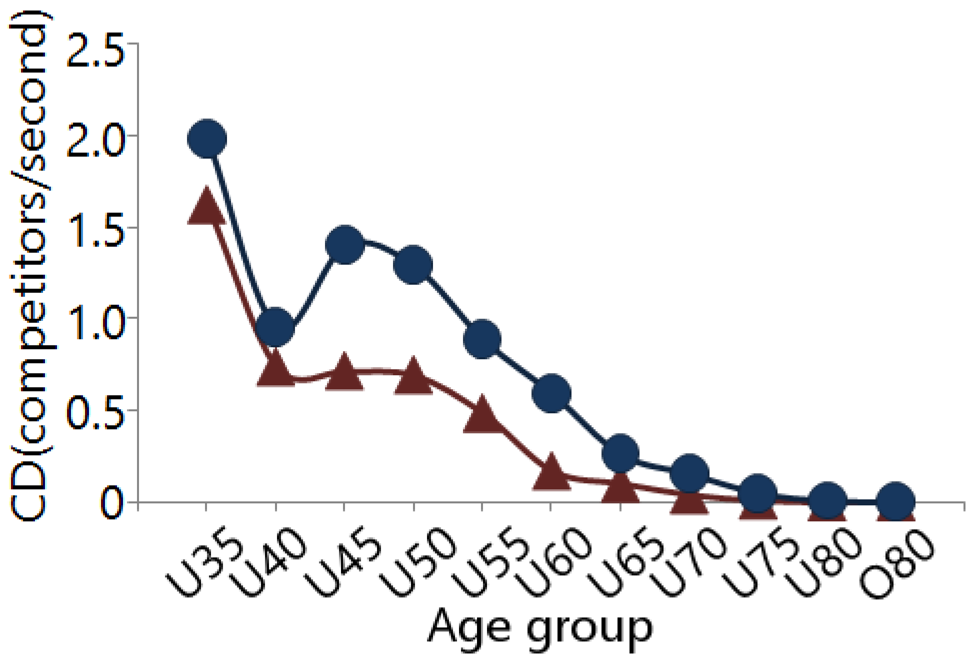
4:00
3:00
2:00
1:00
0:00
Race time (h:min)
Women
Men
U35 U40 U45 U50 U55 U60 U65 U70 U75 U80 O80
Age group

Figure 3



Women
Men
Race time (h:min)
2:13
1:40
1:07
U35 U40 U45 U50 U55 U60 U65 U70 U75 U80 O80
Age group

Figure 4


CD(competitors/second)
2.5
2.0
1.5
1.0
0.5
0
U35
U40
U45
U50
U55
U60
U65
U70
U75
U80
O80
Age group